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of peritoneum. Posteriorly the sex ridges of the two sides are united into a single ridge. There is considerable variation in the rate of segmentation in larvæ of the same size, but the following table will give an idea of the segmentation and the number of cells in successive stages :

Size of larva.	No. of sex cells.	No. of generations from fertilization.
45-5 mm.	9-15	5
8	22	6
10	28-183	6-9
12	39-143	7-9
15-17	638-2280	11-13 sexes distinct.
16-25	2200-8000	13-15

The sexes can first be distinguished not by the differences in the sex cells, but in the tunic of peritoneal cells. A small groove on the outer ventral part of the sex ridge is the first indication of the ovarian cavity and the surest criterion of the female. In the male the sex gland remains much more circular in cross section and no groove is developed. Much later histological differences in the sex cells themselves can be made out. The long slender chromatin threads of the female cell just before dividing are represented in the male by short, thick bars.

THE HISTORY AND PRINCIPLES OF GEOLOGY, AND ITS AIM.

BY J. C. HARTZELL, JR., M. S.

(*Continued from page 183.*)

Lamarck and DeFrance earnestly engaged in study of fossil shells, and the former, in 1802, reconstructed the system of conchology and introduced into it the new species collected by the latter from the strata underlying the city of Paris and quarried for the construction of its buildings. Six years previous to this Cuvier had established the different specific character of fossil and living elephants and he devoted himself to researches throughout the remainder of his life. Jameson, in 1808, pointed out the nature of all the rocks and the mode in which they were formed, and made use of the observations

of Desmorest, who, in 1768, traced the origin of basalt to the crater of volcanoes.

In 1807 the Geological Society of London was established with the professed object of encouraging the collection of data and the making of observations. In 1819 the Society published a map of England by the aid of Greenough. About the same time Buch prepared a similar map of a large part of Germany. A geological survey of France was ordered in 1822 by the French government, and as a result a geological map was published in 1841. Conybeare and Phillips published a treatise on the "Geology of England and Wales," in 1821. In 1814 Aiken published his work on mineralogy, which had a large circulation at home and in this country. Previous to this Sowerby published a work on "British Mineralogy, illustrated with colored plates," but the date of which I do not know. The publication of the Geological Map of England, in 1815, by Smith, may be said to form an epoch in the history of geology.

In 1809 Maclure published an article on "Observations on the Geology of the U. S., explanatory of a Geological Map," and he is rightly called the father of American geology. He visited all parts of the Union and all the principleming ni districts of Europe. In 1817 he presented a report to the "Philosophical Society of Philadelphia" of his work, and accompanied it with a colored map. In 1816 and 1817 he visited the Antilles and published a paper on their geology. In 1810 Bruce, of New York, published the first purely scientific journal supported by original American contributions. His journal was devoted principally to mineralogy and geology. Science was also promoted by the collections in the colleges and societies, and by those made by scientific men. In 1816 Cleveland published a treatise on mineralogy. In 1818 Dana published a detailed report on the mineralogy and geology of Boston and vicinity. In the same year the American Journal of Science was first published. The first geological survey made by State authority was that of North Carolina in 1824.

In 1830 the Principles of Geology, by Lyell, appeared and has most powerfully influenced the direction of scientific

thought in the 19th century. It broke down the belief in the necessity of stupendous convulsions in past times. He adopted and improved the views of Hutton, eliminating the baseless theories mingled with them. He rendered great service in elucidating North American geology, and published his travels on this continent in 1845 and 1849. His "Geological Evidences of the Antiquity of Man," published in 1863, startled the public by its advocacy of Darwin's theory in the "Origin of Species."

And so the science has advanced with rapid strides and is solving the problems that are constantly arising in regard to our planet, and upon its fixed data are based many of the fundamental principles of philosophy.

Having considered the history of the progress of geology, let us now consider its aim and the fundamental principles upon which the geologist bases his work.

In the broadest sense, geology is the science whose province is the planet upon which we live, its history from the beginning to the present, including changes which have occurred in regard to the condition at different periods, its several physiographic features, its atmosphere, temperatures, and aqueous bodies, and its life at different stages. In a nutshell, the evolutionary progress of the earth.

The narrow or commonly accepted view does not consider the changes that have occurred, other than those that occurred to the visible portion of the earth. Back of what is supposed to be the earliest formation, it does not attempt to go.

The latter view is sufficient for the ordinary geologist or for the geologist who does not care to speculate on hypotheses which refer to the origin of the earth; but to the geologist who is anxious to grapple with problems which require a drawing upon the imagination for solution, this is not enough. Chemists are not satisfied to study a drop of water, but they are anxious to know its origin; its composition is not sufficient for them. Botanists and zoologists desire to know the origin of plants and animals, not merely their structural and physiological features.

Geologists who study the earth, not merely to satisfy their own curiosity as to the *present* condition of things, but for the purpose of advancing the science, and unraveling the mysteries of the past, in order to produce a history of the planet as accurately as human knowledge in its present condition will permit, are only satisfied with the broad and comprehensive view.

Geology, by the aid of astronomy and physics, therefore, begins with a great nebulous mass, of which all celestial bodies were component parts. It traces the evolution of each body, and that of the earth in particular. Starting when the earth was thrown off as a ring of cloudy or gaseous elements, it traces it through its transformation into a sphere of molten matter surrounded with gases, through which the parent body, the sun, could not penetrate. We learn of the war that existed between the congealing surface and the liquid interior in which the former came off victorious, and formed a crust through which the latter seldom broke. Then began the war between the condensing vapors and the heated crust, in which the latter succumbed to the overpowering element that fell upon it and fairly covered it.

Geology tells us of the life that existed in this mighty ocean after it became sufficiently cooled, and in the powerful internal movements that resulted in the upheaval of masses of rock that were to be the nuclei of the present continents, the history and the formation of which is traced with great minuteness, and the life of each is described with great care, from the lowest forms to the highest, and also the period in which each form lived.

There are several principles by which the geologist is guided in answering the questions that continually arise as he studies the earth with its many characteristics.

1 In the first place, he understands that *geology is an inductive science*. That is, it is a process of demonstration in which a general truth is gathered from an examination of a self-evident truth. Let me illustrate: From the study of modern glaciers he learns certain facts in regard to conditions necessary for their formation, their modes of action, and the results of those actions.

Now, whenever a geologist sees the results of some great force and those results are similar to the phenomena produced by glaciers, he concludes that at some previous time the conditions were such as to make it possible for glaciers to exist in the locality in which his observations were made, for no other force could produce them.

2 He reasons that *all affects must be referred to secondary causes*. In other words, law governs all phenomena, and forces are so balanced as to produce all *known* and *unknown phenomena*. All events that have transpired in the development and configuration of the earth have been brought about by law. In the formation of glaciers certain laws are obeyed, and those laws are always obeyed unless an equilibrium is sustained between them and some other laws are overbalanced.

When the conditions are favorable for the action of *glacial laws* glaciers will be found. The same principle holds good in the distribution of life.

3. *The forces in existence to-day are capable of producing all phenomena that have and may occur*. Therefore, the geologist must study the methods by which they are producing changes at present, and thereby be able to judge of what took place ages ago, and the manner in which great events transpired. In other words, *the past is understood by the present* and to some extent *the future may also be understood*. No new law is, nor has been, necessary for the explanation of phenomena and, therefore, there have been no accidental happenings. There may be laws that man has not as yet learned the nature of, and they may be so balanced as to be beyond man's comprehension, but that there are being or have been created new laws, and that there are accidents, the geologist does not admit.

4. *The earth is undergoing and therefore has undergone changes*. He sees this in studying the phenomena of denudation and disintegration. He sees that the mountains are being destroyed by chemical and physical agencies, and that they are being gradually carried into the valleys, and then into the sea. This, he reasons, must have been going on ever since the first continent made its appearance.

5. Finally, from a consideration of the above principles, the geologist realizes that his *work must be systematic*, and that the bulk of it *must be done in the field*. *Field investigation is indispensable*. *Laboratory work holds a subordinate position*.

It is safe to say that geology has advanced more rapidly than any other science, and the number of those who are making a specialty is steadily growing. New periodicals devoted to the science are continually appearing, and its literature is quite comprehensive. Very little attention was paid to it in our colleges at no late date, but to-day it occupies a prominent position.

The great advance which has been made is due to systematic field work, followed by laboratory work, and the latter is of but little value from a geological standpoint unless it is based upon accurate field investigation. It is necessary to reduce to a practical formula the data secured in the field, and to have a definite method of procedure, for without such, much time is wasted, and many results that otherwise would have been valuable are entirely lost. Mere conjecture must not be indulged in, but "work persistently back from the seen and known to the unseen and unknown," should be the maxim. Conclusions must not be arrived at too hastily.

Professor Dana once said, "I think it better to doubt until you know. Too many people assert, and then let others doubt." Hence, in drawing conclusions from the results of field and laboratory work, be sure you are right, before giving publicity to them, and if a doubt exists, state it, and be willing to change your theory. Dana says, "I always like to change when I can make a change for the better."

It is obvious, from what I have said, that geology is a field science. Different characteristics of the earth's surface cannot always be taken into the laboratory for study at leisure, and it is necessary to see the objects under study if we would arrive at correct conclusions and fix them indelibly in our minds. Facts then become real, and we acquire a correct understanding in regard to the forces that have been at work preparing this planet for man.

It is necessary to have a knowledge of other sciences if one would make practical use of geology, that is, to understand the many phenomena that are presented to him.

Natural philosophy and chemistry are necessary in order to determine the composition of rocks and to understand how they were formed and changed. Botany is necessary to understand paleobotany, zoölogy is necessary to understand paleozoölogy, astronomy figures very prominently in the determination of the relations of this planet to other heavenly bodies. Anything that the telescope and the spectroscope reveal is of geological importance, and bears upon the past and future condition of the earth. Mathematics is constantly in use, and without that science little or nothing could be accomplished.

The foundation work of a geologist, therefore, should be a knowledge of the natural sciences, for without them he will be materially hampered in his work.

Geology is practical as well as literary in nature. Every agriculturalist would become more scientific, and would reap better "crops" if he had a knowledge of the science, for it gives a knowledge of soils and fertilizers. To the engineer it is of great importance, for thereby he understands drainage and the best methods for excavating. It is of great importance to the manufacturer, for he can better understand clays, ores, fuels, etc., and in mining it is of great value for it enables the miner to understand the nature of the rock in which the metals occur and assists him in "prospecting."

This use of the science is termed "Economic Geology" and is of inestimable value and importance in developing systematically the resources of a state or of a nation.

The United States government has realized the importance of thorough and accurate investigation of this vast country of ours from an economic standpoint, and established the U. S. Geo. Survey in 1879 for this purpose. Most of the states have their surveys and work for the same ends, but on a smaller scale, and assist, and are assisted by, the government survey, and so work in harmony with each other.

Individuals are at work gathering information in regard to particular formations, correcting mistakes, advancing new theories, devising new plans for more thorough and accurate works and imbuing students with the grandeur of the science.

What is there more sublime than a science that reveals the universe in all its beauty and grandeur and as the result of the balancing of forces which emanate from a creative will? Geology reviews the history of the planet from the earliest known formation to the present. Back of this it goes by retrograde calculation, and hence we have a complete resumé from the time "the earth was without form and void," to the phenomena observed to-day. It tells us of periods of time of immeasurable duration, during which was being molded that upon which it would be possible for life to exist, and over which mind should rule.

There is no science which presents so many problems to be studied, nor in which so much of interest can be taken. It carries one over plains, up the rugged mountains and down into valleys. On every hand is found something new upon which to concentrate the mind, and which demands a satisfactory explanation. How came these plains, these mountains, these valleys? How came those masses of rock, thousands of feet high? Why is sandstone here, limestone there, and granite yonder? What mean those remains of animals and plants that are not in existence to-day? Why are those masses of rock in every conceivable position? Whence came the waters and the land? The plants and animals? Is there a reason for all we see? Are these things accidental, or was there a purpose in their formation?

And so questions crowd upon us, and fill us with wonder and admiration, and with a determination not to be satisfied until they are answered. We see that law is at work, fashioning the universe, and we have brought very forcibly to our minds the fact that there was a purpose involved in the creation of the universe, and that from this realized grand conception is being evolved a divine purpose. That which at first appeared to be outside the domain of law, is seen to be the result of the balancing of forces; and we come to realize the fact

that law pervades the universe, and although we do not know as yet the way in which these laws are balanced to produce all phenomena, that they are so balanced as to produce harmony, and that in proportion as the human mind develops it will be capable of grappling with problems that are not now within its reach.

LIFE BEFORE FOSSILS.

BY CHARLES MORRIS.

(*Continued from page 188.*)

Such a new stage of existence may have been essayed frequently. The dwellers in the early seas, in their descents below the surface, must often have come into contact with the bottom, and at times temporarily rested upon it. This contact with hard substance doubtless produced some effect upon them, and certain variations in structure may have proved of advantage in these new circumstances and been retained and further developed. Particularly if food was found there, and habitation on or near the bottom was thus encouraged, would such favoring variations tend to be preserved.

But, as has been said, myriads of years may have passed in the slow development of swimming pelagic animals before this phase of evolution was completed. And, perhaps, not until this was fully accomplished did contact with the bottom set in train a new series of changes, and in time give rise to the greatly transformed bottom-dwellers. The change, indeed, was a great one, if we may judge by the wide diversity in character between the swimming embryos and the mature forms of oceanic invertebrates, and must have needed a long period of contact with the bottom for its completion. Yet it was probably much more rapid than had been the preceding pelagic development. Contact with solid substance was a decided change in condition, and may have greatly increased